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THE EFFECT OF LAUNDERING UPON LICE (*PEDICULUS CORPORIS*) AND THEIR EGGS *

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At the request of Dr. Richard M. Pearce of the National Research Council, on July 25, the author took up the question of the effect of the ordinary steam laundry processes upon lice and their eggs. The object of the investigation was to determine to what extent these processes were destructive to both lice and eggs, and should they prove to be inefficient, what slight alterations could be made in the regular routine to make them effective.

LAUNDRY PROCESSES

Through the courtesy of Mr. J. Clair Stone, manager of the Elk Laundry, St. Paul, I was able to study the processes encountered in the washing of regulation army clothing. The clothing may be divided into three types: rough cotton goods (including cotton underwear), cotton khaki wear, and woolen goods (including garments part wool and part cotton). Altho the procedure differs somewhat in different steam laundries, they may in general be outlined as follows:

	Baths	Temperature	Time
Cotton Goods	1st Water	100° F. (37.7° C.)	5 min.
	2nd Neutral Soap	180° F. (82.2° C.)	15 min.
	3rd Neutral Soap	180° F. (82.2° C.)	15 min.
	4th Soda Bath	130° F. (54.4° C.)	10 min.
	5th Water	130° F. (54.4° C.)	5 min.

Cotton goods are dried in the hot air tumbler at a temperature of 150° F. (65.5° C.) to 190° F. (87.7° C.) until quite dry. Time about 20 minutes depending upon the load.

	Baths	Temperature	Time
Cotton Khaki	1st Water	100° F. (37.7° C.)	5 min.
	2nd Neutral Soap	120° F.-130° F. (48.8° C.-54.4° C.)	15-20 min.
	3rd Water	130° F. (54.4° C.)	5 min.

Dried in the hot air tumbler at 150° F. (65.5° C.) to 180° F. (82.2° C.) until just sufficient moisture is left in the garment that it may be pressed. Time about 10 to 15 minutes depending upon the size of the load. Pressed in the Universal Press.

	Baths	Temperature	Time
Woolen Goods	1st Neutral Soap	110° F.-115° F. (43.3° C.-46.1° C.)	15 min.
	2nd Water	110° F.-115° F. (43.3° C.-46.1° C.)	3 min.

Woolens are dried at room temperature and never in the hot air tumbler.

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The first important point to determine was what effect the temperatures encountered would have upon the lice and nits. Data were available from the work of other investigations giving an indication of what results might be expected. The following table was taken from a compilation of Nuttall (1918).

IMMERSION OF EGGS IN HOT WATER

Temp., Degrees F.	C.	Time	Result	Observer
192	88	15 sec.	Killed	Nuttall
169	76	30 sec.	Killed	Nuttall
158	70	10 sec.	Killed	Nuttall
150	67	1 min.	Killed	Nuttall
140	60	5 min.	Killed	Nuttall
140	60	5 min.	Killed	Widmann
131	55	10 min.	Killed	Widmann
131	55	30 min.	Killed	Bacot
129	54	10 min.	Killed	Nuttall
121	50	15 min.	Killed	Widmann
112	45	15 min.	Not Killed	Widmann
104	40	1 day	Not Killed	Widmann

EXPOSURE OF EGGS TO DRY HEAT

124	51.5	15 min.	Not Killed	Experiments of Capt. Orr, Canadian A. M. C., and Bacot
127	53	15 min.	Not Killed	
130.5	55	30 min.	Killed	
132.5	56	20 min.	Killed	
134	57	30 min.	Killed	
152	57	15 min.	Killed	

EXPERIMENTS

In my experiments, it was found that the quantity of soap used varied somewhat due to the hardness of the water. Sufficient soap was added to the water to give a good suds. It was found that with the water used in the experiments recorded below that 1 gram of ivory soap (neutral) and ⅓ gram of soda added to 265 c.c. of water furnished the desired suds. Inasmuch as the eggs are more difficult to destroy than the active stages, particular attention was paid to them. All the eggs were from lice collected from infected clothing, and kept in an incubator heated to 28° to 32° C. The eggs were laid upon small squares of cloth during the week of July 27 to August 2, in Exp. 1 to 6, and from July 27 to August 7 in Exp. 7 to 12. Each piece of cloth therefore represented eggs in different degrees of development.

Experiment 1.—Control set: 42 eggs; 78½% hatched.

Experiment 2.—Woolen Goods Treatment. Soaked in suds heated to 110° F.-114° F. (43.3 C.-45 C.) for 15 minutes. Rinsed in water of same temperature for 3 minutes, dried on a piece of filter paper and returned to the incubator; 65 eggs 92% hatched.

Experiment 3.—Khaki Wear Treatment. Soaked in suds heated to 121-126 F. (49-52.2 C.); average temperature, 123 F. (50.5 C.), for 15 minutes. Rinsed in water 123 F. (50.5 C.) for 4 minutes. Dried and returned to incubator; 38 eggs 39% hatched.

Experiment 4.—Khaki Wear Treatment. Same as Experiment 3 except treatment was for 30 minutes. 45 eggs, 0% hatched.

Experiment 5.—Cotton Goods Treatment.—Soaked in suds at 170-186 F. (76.6-85.5 C.), average temperature 179 F. (81.6 C.), for 30 minutes. Rinsed in water 130 F. (54.4 C.) for 5 minutes. Dried and returned to incubator; 52 eggs, 0% hatched.

The following experiments were conducted to determine the effect of treatment in the hot air tumbler and pressing in the Universal Press upon the eggs of the louse.

Experiment 6.—Eggs placed in pocket of a bathrobe in the hot air tumbler carrying a heavy load. Tumbler had been running for 5 minutes before eggs were placed in it. Eggs in the tumbler for 10 minutes and garments were quite moist when eggs were removed. Eggs replaced in incubator after treatment. 88 eggs, 0% hatched.

Experiment 7.—Control, 48 eggs. 100% hatched.

Experiment 8.—Cloth, upon which the eggs were laid, wet and then placed in the pocket of a pair of khaki trousers which was tumbled with others for 15 minutes. Load light and removed while still damp. Regular practice of drying khaki wear. 146 eggs, 0% hatched.

Experiment 9.—Eggs placed in pocket of partly dried bathrobe. Light load of clothing, tumbled for 10 minutes. 53 eggs, 0% hatched.

Experiment 10.—Same as Experiment 9, but tumbled for 15 minutes; 73 eggs, 0% hatched.

Experiment 11.—Same as Experiment 10, but tumbled for 20 minutes; clothing quite dry when removed. Regular cotton goods treatment. 57 eggs, 0% hatched.

Experiment 12.—Cloth with eggs placed under pocket of a pair of khaki trousers being pressed in the Universal Press. After treatment removed to incubator. 61 eggs, 0% hatched.

The recorded experiments upon the effect of soap suds at different temperatures upon the eggs of the lice would lead one to suppose that active stages would also be destroyed in those experiments where the suds had proved destructive to the eggs. To verify this, the following experiments were conducted.

Experiment 13.—Twelve recently fed lice in different stages of development were dipped in suds at 110-114 F. (43.3-45 C.) for 15 minutes, rinsed in water at 112 F. (44.4 C.) and dried on filter paper. All revived within a few hours.

Experiment 14.—Same as Experiment 13, but suds at 122-126 F. (50-52.2 C.), average temperature 124 F. (51.1 C.) for 15 minutes. All lice killed by treatment turning reddish brown within 5 hours.

Experiment 15.—Same as Experiment 14, but exposure lasting 30 minutes. All lice killed.

The experiments show that in the washing of rough cotton goods at 180° F.—82.2° C. for 15 or 30 minutes, will destroy the lice and their eggs. If by any chance an egg should escape destruction in the washing process they would later be destroyed during drying in the hot air tumbler. Washing cotton khaki clothing at a temperature of

120° to 130° F. (48.8° to 54.4° C.) for 15 minutes would prove destructive to the active stages, but would not completely destroy the eggs. Washing for 30 minutes, however, proved destructive to the eggs. Drying khaki uniforms in the hot air tumbler would also destroy any eggs that might have escaped the action of the hot suds. Pressing in the Universal Press was also effective, but this treatment cannot be relied upon to destroy all the eggs in an infested suit as portions of the uniform may not be touched. Neither the lice nor their eggs were destroyed in the woolen goods by the regular washing and since they are dried at room temperature, to avoid shrinkage, the problem resolved itself into devising some method of laundering woolens that would prove destructive. The first method which suggested itself was the treatment of the woolen goods in the hot air tumbler for 10 to 15 minutes before they are washed and while still dry. Nuttall (1918) claims "that the moderate degree of dry heat necessary to kill vermin will not prove injurious to wool, but that high temperatures 104° C. acting for 4 hours whilst but slightly yellowing white flannel does not affect its tensile strength, but if exposed to 127° C. for half an hour, flannel yellows and becomes brittle." This method, however, is open to two objections; namely, the danger of reinfestation of clean garments from handling garments infested with active stages in the vicinity of the tumbler, and the coagulating effect of the hot air on stains of blood, excreta, and other proteins, which may be present on garments before they are washed. Both these objections would be removed if the garments were first washed in such a manner as to destroy the active stages. The garments after drying could then be run in the tumbler to destroy all eggs which had escaped destruction during the washing.

In other experiments on contact insecticides (Moore and Graham, 1918) it had been found that where the insecticide possessed both wetting and spreading properties, the insecticide entered the tracheae of the insect, thus bringing about its death. Fat solvents, oils, etc., together with soap possessed such properties. Ivory soap, however, was found to possess great cohesion, thus preventing it from readily entering the tracheae. By raising the temperature of the solution or diluting it with water, the cohesion was reduced. From these results, it was not apparent why the suds used in the previous experiments (13) at a temperature of 110° F. to 114° F. (33.3° to 45° C.) should not have killed the active stages of the lice. The following experiments were conducted to throw more light on this point.

Experiment 16.—Lice not fed for 5 hours were dipped in a ivory soap solution of 1 gram to 100 c.c. of water colored blue with trypan blue. Temperature 108-115 F. (42.2-46.1 C.). Lice removed in 15 minutes and examined by mounting in alcohol on a glass slide, but no trace of the colored soap solution could be found in the tracheae.

Experiment 17.—Same as Experiment 16, but soap solution 1:250 c.c., results negative.

Experiment 18.—Same as Experiment 16, but soap solution 1:500 c.c., results negative.

Experiment 19.—Same as Experiment 16, but soap solution 1:750 c.c., results negative.

Experiment 20.—Same as Experiment 16, but soap solution 1:1,000 c.c., results negative.

Experiment 21.—Same as Experiment 18, but soap solution at a temperature of 122-132 F. (50-55.5 C.). Lice were killed by the treatment but no trace of the solution could be found in the tracheae.

Experiment 22.—Lice placed in soap solution 1:500 at room temperature at 8:13 a. m. and removed at 3:30 p. m. No trace of soap solution in tracheae of specimens examined. Lice divided into two lots; one rinsed in water; the other not rinsed. Both sets revived within an hour.

Since it appeared impossible for the ivory soap solution to enter the tracheae, a solution of castile soap with much lower cohesion was used but similar negative results were obtained. Soap solutions having failed to enter the tracheae, the question arose as to whether fat solvents or oils could penetrate.

Experiment 23.—Lice dipped in xylene stained with sudan III were examined at the end of 5 minutes but no trace of the stain could be found in the tracheae.

Experiment 24.—Lice dipped in ether stained with sudan III. One specimen examined after two minutes but no stain was detected. Stained ether was found in few tracheae of a louse in the ether for 5 minutes but none was found in a specimen removed after 8 minutes.

Experiment 25.—Twelve lice dipped in ether stained with sudan III for 10 minutes. Examination showed 7 with no ether in the tracheae and 5 which had ether in several tracheae but none with ether in all the tracheae.

Experiment 26.—Four lice dipped in a light lubricating oil stained with sudan III. Removed after 15 minutes, but no stain could be detected in the tracheae.

Most of the lice in these experiments were dead when removed from the liquid, having been killed by the chemical passing directly thru the body wall, since no stain could be detected in the alimentary canal. Landois (1865) has figured the closing apparatus of the pubic louse which is similar to that of the clothes louse and from the above experiments, the conclusion is reached that the louse is able to close this apparatus very quickly, but occasionally, as in the case of ether, a few tracheae are not closed quickly enough to keep out the chemical. A few experiments showed that the tracheae of the dog flea (*Pulex serraticeps*) was filled with stained ether after 1 minute immersion, but that the hog louse (*Haematopinus suis*) and the dog louse (*Haematopinus piliferus*) were somewhat resistant to its penetration, but not nearly so successful as the clothes louse. It is hoped to investigate this interesting observation more fully at some later date.

Two possible methods of killing the active stages is suggested by these results: First, the addition of a chemical to the washing suds capable of penetrating the chitin of the body wall during the period of washing, and toxic enough to produce its death, and second, the elevation of the temperature of the washing suds sufficiently high to destroy the lice. In general, a chemical capable of penetrating the body wall during the period of washing would have to be rather volatile and hence not suitable for the work. Judging from published accounts, soaking garments in a bath containing cresol or lysol is practiced to a large extent in Europe. The garments, however, are not rinsed following their dip. Peacock (1916) found a 1½ per cent. cold cresol solution to be capable of destroying the lice and nits soaked in it for one hour. Nuttall (1918) found a 5 per cent. cresol and soap solution to kill lice and nits in 30 minutes, while a 2 per cent. lysol solution at 76° F. (24.3° C.) killed the eggs after 5 minutes exposure. Bacot and Lloyd (1918) considers that "the evidence as a whole seems to establish the fact that steeping for twenty minutes in a 2 per cent. solution, either lysol or the cresol soap, is quite effective provided the temperature is not below 50° F." The following experiments were conducted to determine the efficacy of cresol either as a dip preceding washing, or when used in the wash suds.

Experiment 27.—Dipped 12 recently fed lice in suds with 1% tricresol added. Temperature 75 F. (24 C.). Removed after 5 minutes to suds at 110-114 F. (43.3-45 C.) for 15 minutes, rinsing in water at 112 F. (44.4 C.) for 3 minutes. Dried on filter paper when 10 lice revived.

Experiment 28.—Same as Experiment 27, but cresol suds at temperature of 110-114 F. (43.3-45 C.), 9 lice revived out of 16 used in the experiment.

Experiment 29.—Dipped recently fed lice in 1% tricresol in ivory soap suds at 110-114 F. (43.3-45 C.) for 15 minutes, rinsing in water at 112 F. (44.4 C.) for 3 minutes. Dried when one revived out of 17 lice.

Experiment 30.—Dipped in 2% tricresol in suds at 110-114 F. (43.3-45 C.) for 5 minutes. Placed in regular suds at 110-114 F. (43.3-45 C.) for 15 minutes, rinsing in water at 112 F (44.4 C.). Dried, no lice revived.

Experiment 31.—Same as Experiment 30, but with 3% tricresol. All lice killed by the treatment.

From these results, it is apparent that 2 per cent. crude tricresol may be added to the washing suds or used as a dip preceding washing and prove effective in the destruction of the lice in the active stages. Although the pieces of cloth were rinsed after treatment, an odor of cresol persisted, apparently being rather difficult to remove.

Bacot and Lloyd (1918) point out that cresol emulsions are liable to decrease in insecticidal value in the presence of organic impurities. To what extent this action takes place is not known and possibly varies greatly. Such being the case and in view of the increased cost of

using a chemical to destroy the lice, further experiments were made to determine to what extent heat might be used. A summary of these experiments follows.

SUMMARY OF 30 MINUTE TREATMENTS

Temperatures	Dead	Revived
108-110 F., Average 108.8 F., 42.6 C.....	1	7
110-113 F., Average 110.7 F., 43.7 C.....	3	7
110-115 F., Average 111.6 F., 44.2 C.....	1	16
109-115 F., Average 112.4 F., 44.6 C.....	15	1
110-115 F., Average 113 F., 45 C.....	18	0
112-114 F., Average 113 F., 45 C.....	15	0

SUMMARY OF 22 MINUTE TREATMENTS

110-116 F., Average 112.8 F., 44.8 C.....	10	0
113-115 F., Average 114.2 F., 45.6 C.....	10	0
114-117 F., Average 115.2 F., 46.2 C.....	8	0

SUMMARY OF 15 MINUTE TREATMENTS

111-115 F., Average 112.3 F., 44.6 C.....	6	8
111-115 F., Average 113 F., 45 C.....	11	0
111-115 F., Average 113.3 F., 45 C.....	9	9
112-116 F., Average 114 F., 45.5 C.....	10	2
112.5-116 F., Average 114.2 F., 45.6 C....	18	0
113.5-117 F., Average 114.9 F., 46 C.....	8	0
115.5-117.5 F., Average 116.5 F., 46.9 C..	6	0

These experiments show the lethal temperature for lice is about 113° F. (45° C.) for 22 to 30 minute washings, and a slightly higher temperature 114.5° F. (45.8° C.) proved effective in 15 minutes' time. When woolen garments are quite soiled, the usual practice in laundries is to wash them at the higher temperature of 120° to 125° F. (48.8° to 51.6° C.), care being taken to keep the temperature constant thruout the process which is the important point in washing woolens to prevent shrinkage. These temperatures may be easily maintained in the washing machine.

Considering the data presented, the following procedure is recommended for the laundering of woolen goods to destroy both lice and eggs. Infested garments to be washed at a temperature of 120° F. (48.8° C.) not to fall below 115° F. (46.1° C.) during the washing period of 15 minutes, this treatment to destroy the active stages without the use of any special chemicals. Garments are then treated in the regular manner until perfectly dry, when they should be placed in the hot air tumbler at a temperature of 150° to 170° F. (65.5° C. to 76.6° C.) for 10 to 15 minutes resulting in the destruction of the eggs. By this method, it will be possible to launder woolens without shrinkage, and destroy the lice and eggs without the use of a special chemical.

These experiments have been corroborated in general by the experiments conducted with the regular army laundering units by W. Dwight Pierce and Lieut. A. Moscowitz. In their experiments, the woolens were washed at a slightly higher temperature, 131° F., and dried in the hot air tumbler without shrinkage resulting.

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